Final Report on Acceptance Testing

Phase One of NASA

Nickel-Cadmium Battery Test Project

Contract No. NAS5-3027

ER 13179

Martin Marietta Corporation
Baltimore, Maryland

October, 1963

CONTENTS

ILLUSTRATIONS

TABLES AND GRAPHS

1.0 Purpose of Nickel-Cadmium Cell Acceptance Testing

The purpose of the acceptance tests was to define the capacity of the cells, to eliminate those cells with markedly variant electrical properties, such as capacity and end charging voltage, and to eliminate all cells with defects such as leaks and internal shorts.

The mean ampere-hour capacity of all accepted cells will be utilized during Phase Two of the Nickel Cadmium Battery Project, Cycling Tests, in determining the charge/discharge rates on selected batteries. Comparisons will be made between the data obtained during Phase One and the data to be obtained during Phase Two, and correlation of this data will later be attempted.

In addition to the above objectives it is hoped that further investigation into the cause of the abnormal behavior exhibited by certain groups of cells in regards to an over-voltage condition will materially aid the efforts of discovering and defining the cause of cell failures.

2.0 General Description

2.1 Acceptance Tests

To facilitate rapid processing the cell acceptance testing was conducted on a production line basis. Groups of ten cells were tested on a six position line, illustrated in the Acceptance Test Functional Block Diagram, Figure 1, as stations 1 through 6. The operation of each station is described in detail below.

2.1.1 Preliminary Operations

The cells as received were engraved with an identifying code number, and assigned a correspondingly numbered file card on which was recorded the manufacturer's serial number. A one-half ohm resistor was then connected across the terminals of each cell for a three hour period to effect a complete discharge.

The lucite supports on each cell were removed and the cells washed thoroughly with detergent and water, rinsed with tap water, rinsed with distilled water and dried with a clean towel.

All cells were then equipped with two 3/16 inch black-anodized aluminum pressure plates and two aluminum bushing terminal-adapters and copper bus terminal extenders. These terminal adapters and extenders were installed to provide a degree of assurance against accidental short circuits of the positive cell terminal to the negative case during connect/disconnect operations, and to provide a convenient means for mating a quick-disconnect connector to the cell terminals. Wooden cell holders were manufactured to hold a 10 cell group, or battery, in a manner that resulted in maximum visibility of the pressure gauges, and permitted satisfactory placement of 12 batteries in a commercial environmental chamber. As a last step "Operational Flow Tags" were tied to the first cell of each battery to facilitate battery movement and to insure complete testing of all cells.

ACCEPTANCE TEST

FUNCTIONAL BLOCK DIAGRAM

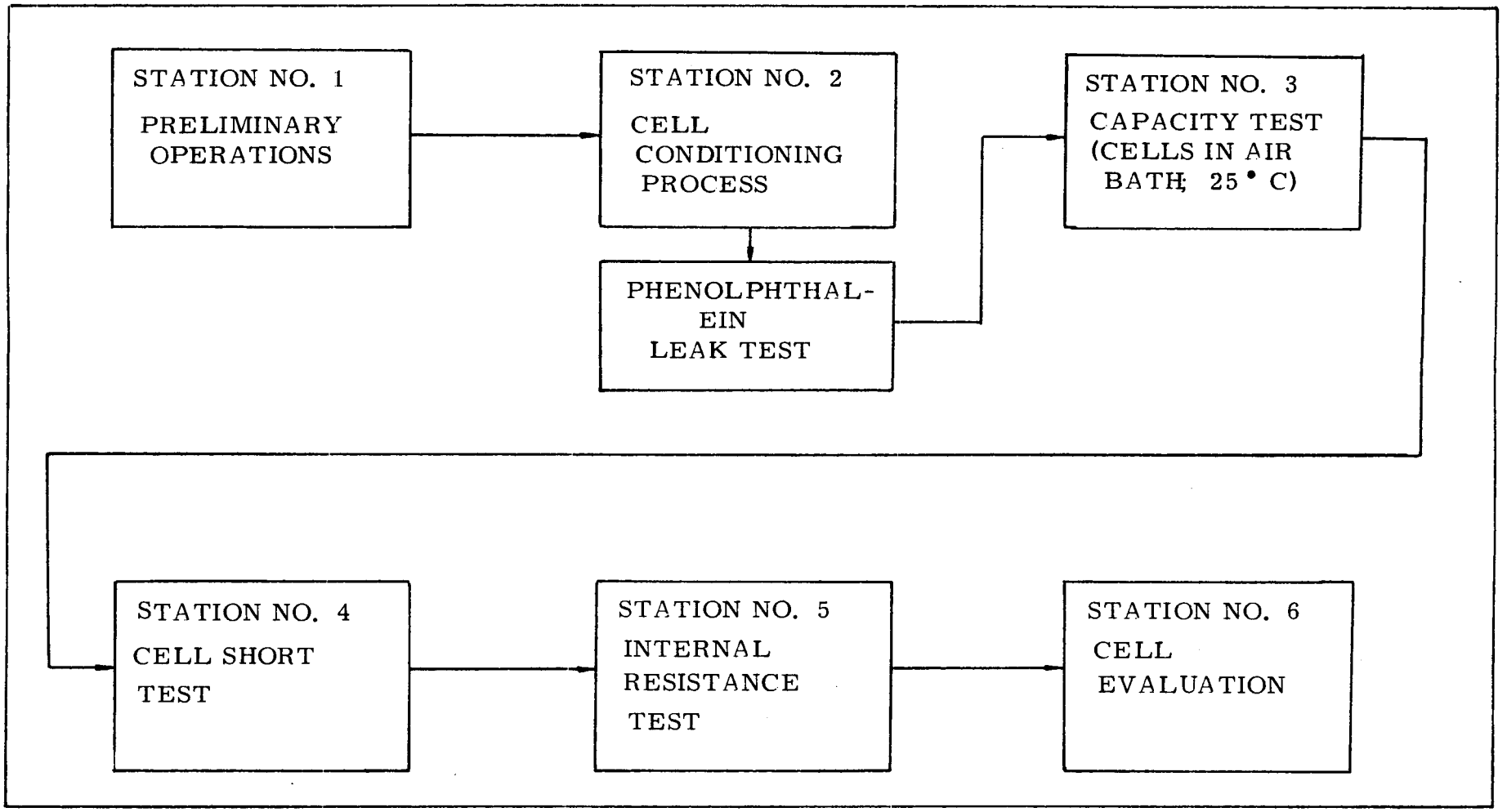
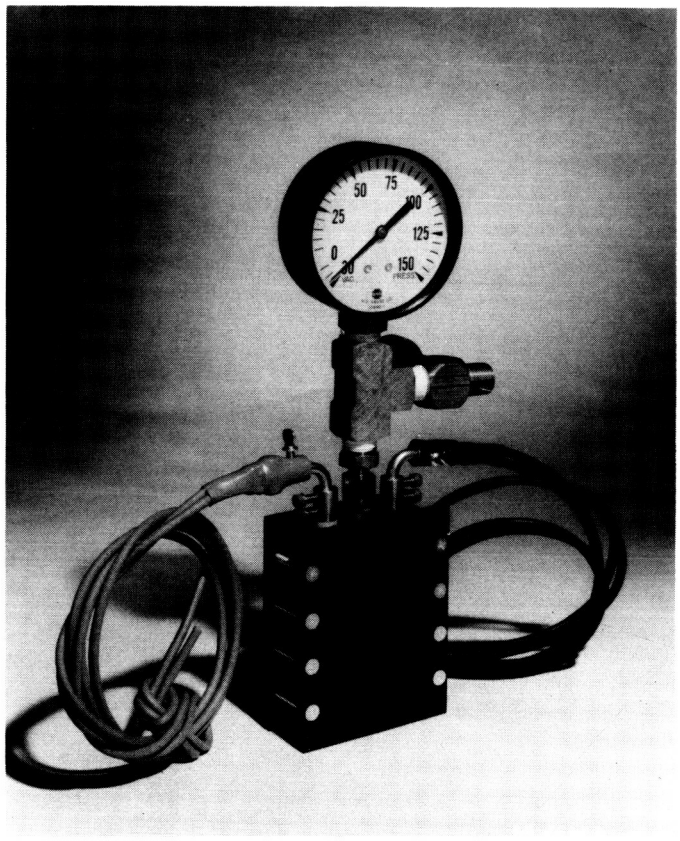
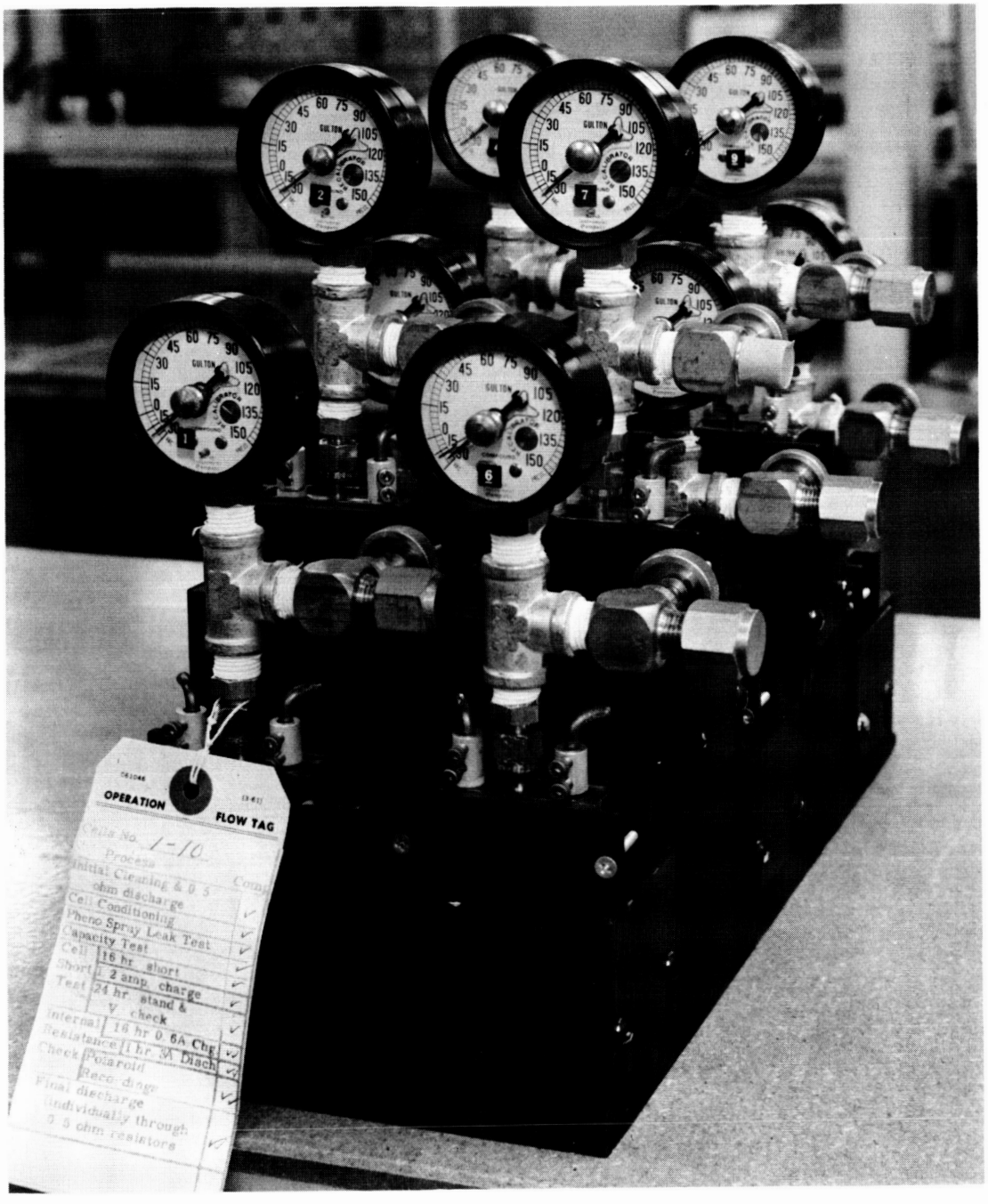


FIGURE 1



Nickel Cadmium Cell with Pressure Plates and Terminal Adapters

FIGURE 2



Cell Holder

FIGURE 3

2.1.2 Cell Conditioning

Cell Conditioning consisted of three charge-discharge cycles followed by a 16 hour short circuit. The charge half cycle consisted of a 13 hour constant voltage charge to an end cell terminal emf of between 1.43 and 1.45 volts.

Following the charge, the cells were discharged through individual one-half ohm resistors for 4.5 hours.

The cells were disconnected after the 16 hour short circuit period, shorted again with short test leads and moved the next position: The Phenolphthalein leak test.

2.1.3 Phenolphthalein leak test

Each cell was checked for caustic leaks by swabbing neutral phenolphthalein solution on the cells and checking for any red indications. The appearance of a red color was interpreted as indicating a leak and was cause for rejection of the cell.

After the leak test, the cells were rinsed thoroughly with distilled water and dried with a clean paper towel.

2.1.4 Capacity Test

Capacity testing consisted of three charge-stand-discharge cycles. A constant current charge of 0.600 amps for 16 hours, followed by an open circuit stand time of one hour, and then a constant current 2.6 amp. discharge to 1.0 volt is representative of a typical cycle. The capacity of each cell of the ten cell group under test at this station was obtained by multiplying the constant discharge current by the individually recorded time required for each cell to discharge to 1.0 volt.

2.1.4 continued

During the capacity test the cell voltages were sensed every 6 seconds and recorded on paper tape every 10 minutes. Pressure readings on batteries no. 1 and 2 were recorded at the end of charges no. 1 and 2 and every 15 minutes during the third charge. On all other batteries with pressure gauges, pressure readings were recorded at the end of charges 1 and 2 and every 15 minutes during the last 6 hours of the third charge. The cells were thermostated at 25 degrees C during the entire capacity test.

2.1.5 Cell Short Test

Following the last cycle of the above capacity test the cells were discharged through a one-half ohm resistor for one-half hour; then short circuited for 16 hours. At the end of this period the cells were charged at 1.2 amps for one minute and then left on open circuit for 24 hours. Each cell voltage was then checked with a high impedance voltmeter and all cells having an emf of less than 1.0 volt were rejected.

2.1.6 Internal Resistance Test

Each ten cell group was charged at 0.6 amps for 16 hours, then discharged at 3.0 amps for 1 hour. The discharge rate was then adjusted to 0.3 amps and continued at this rate until the cell voltage stabilized. Each individual cell was then subjected to a 5 to 8 second discharge at 6 amps. The cell voltage immediately prior to this discharge and 5 milliseconds after the start of the discharge was recorded on a photograph of an oscilloscope trace, the oscilloscope being suitably connected into the system to display the two voltage levels mentioned above. The internal resistance of each cell was then calculated using the following formula

$$R = \frac{V_1 - V_2}{C - C/20}$$

2.1.6 continued

where R = internal resistance of the cell

V_1 = cell voltage immediately prior to the 6 amp discharge

V_2 = cell voltage 5 milliseconds after start of the 6 amp. discharge

C = Nominal cell capacity in amp-hours = 6

2.2 Test Equipment

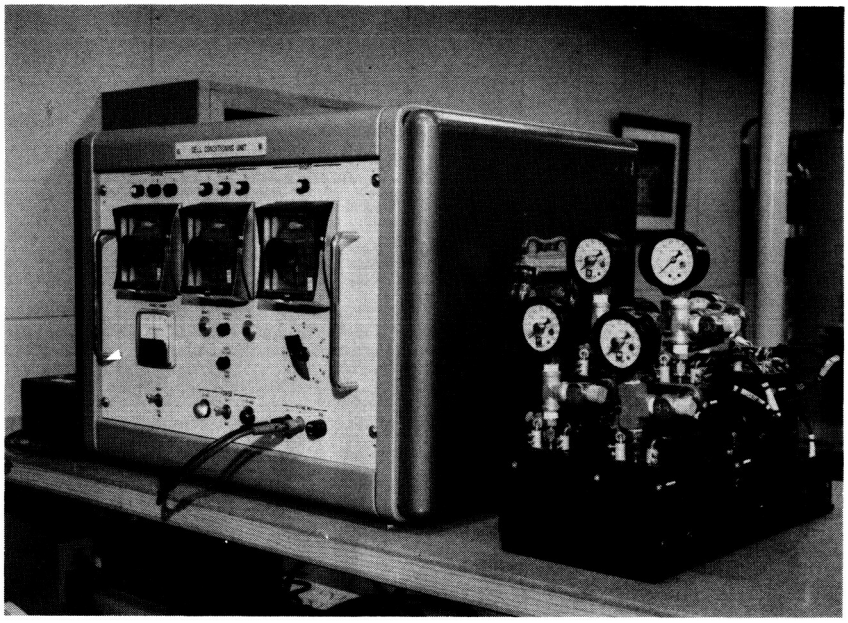
The major pieces of test equipment used in performance of the acceptance tests are described in functional detail below.

2.2.1 Cell Conditioning Unit

The following description is made with reference to the Cell Conditioning Unit Functional Block Diagram.

Depressing the "Start" button moves the sequence stepper to position no. 1, where the charge timer (0-30 hr) is started. The charge switching unit is energized by the charge timer, thereby connecting the voltage regulator output to the 10 paralleled cells in the output line. When the charge timer has timed out, a step signal is sent to the sequence stepper which moves the stepper to position #2. Thus the charge switching unit is de-energized, the discharge timer (0-10 hr) is started, and the discharge relays are energized, connecting individual one-half ohm resistors across each cell. When the discharge timer has timed out, a step signal, is sent to the sequence stepper which moves the stepper to position #3. At position #3 the charge half-cycle is again repeated. This sequence of operation is continued until a total of three charges and three discharges have been completed, and the sequence stepper is positioned at step #7. Position #7, in a manner similar to that described above, short-circuits the output cells for a prescribed length of time (0 to 30 hrs.) the completion of which automatically open circuits the cells and gives a visual indication of process completion.

The unit is equipped with a fail-safe overvoltage switch which automatically disconnects the charge circuit from the cells in the event of any regulator failure which would cause the output voltage to rise out of control. Also, the output current or any of the cell voltages may be monitored at the front panel by either the Charge Current meter or the selector switch connected "Voltage Monitor" jacks.



Cell
Conditioning Unit

FIGURE 4

CELL CONDITIONING UNIT FUNCTIONAL BLOCK DIAGRAM

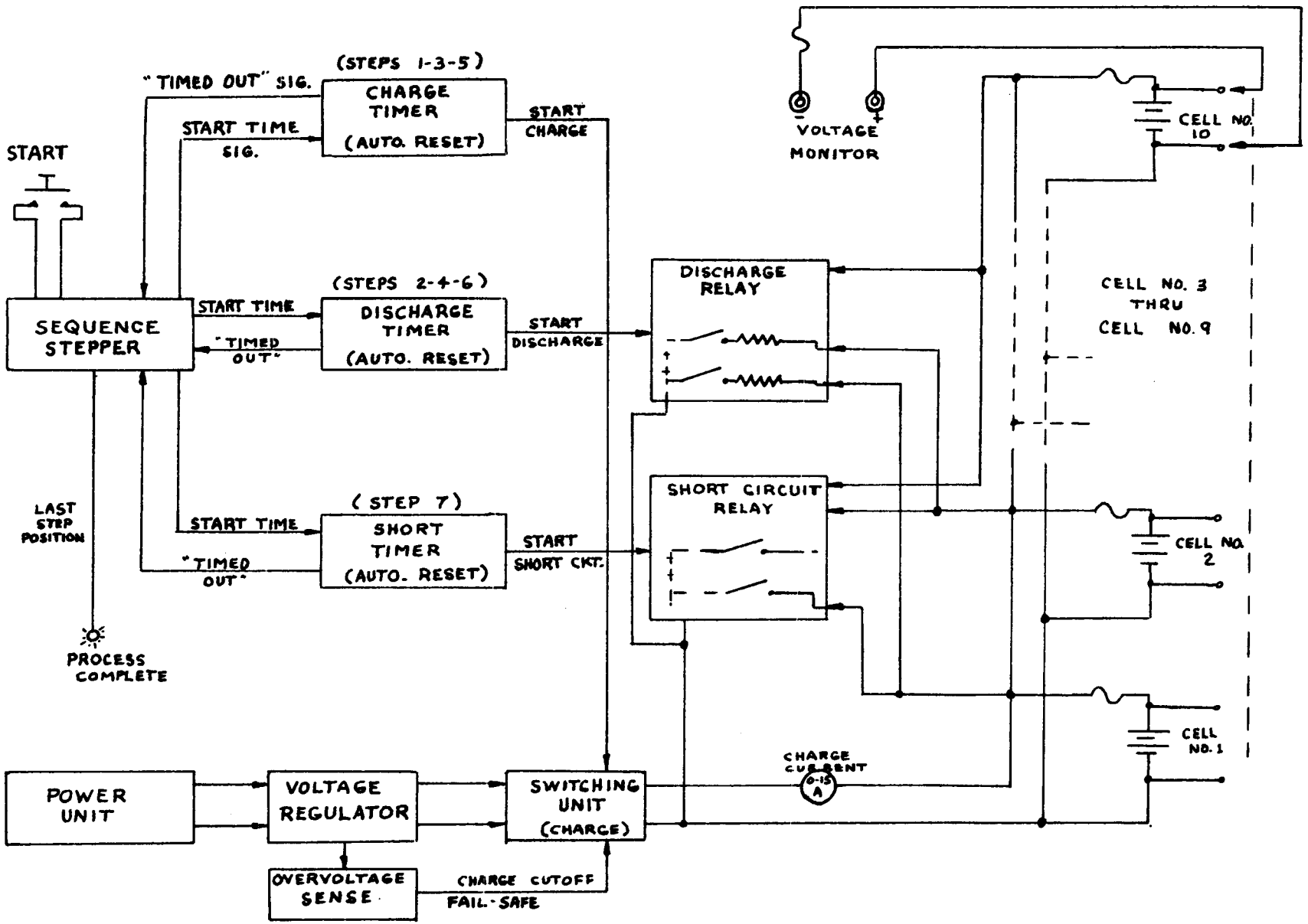


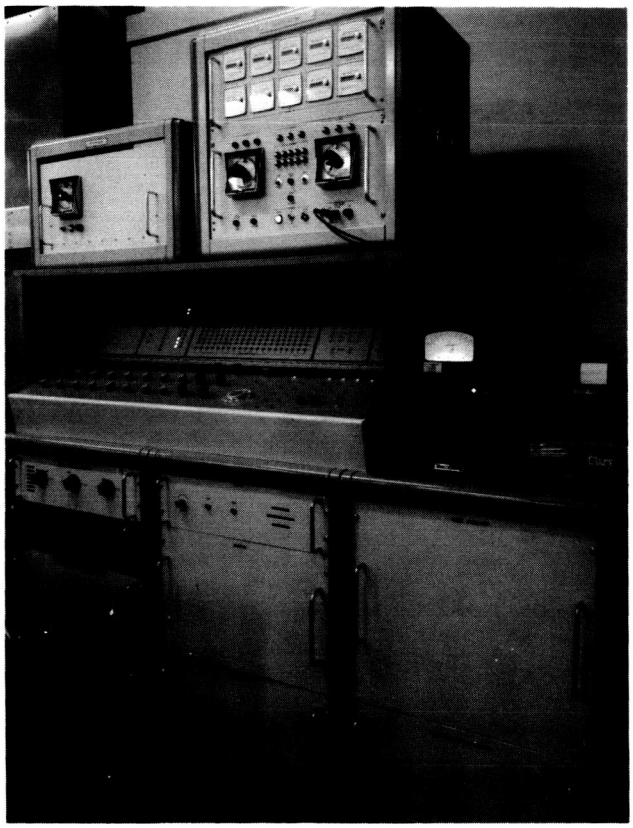
FIGURE 5

2. 2. 2 Capacity Test Unit

The following description is made with reference to the Capacity Test Unit Functional Block Diagram.

Depressing the "Start" button moves the sequence stepper to position no. 1, where the charge timer (0 to 30 hrs.) is started. The charge switching unit is energized by the charge timer, thereby connecting the constant current charge regulator (0. 6A) to the 10 series connected cells in the output. When the charge timer has timed out, a step signal is sent to the sequence stepper which moves the stepper to position #2. Thus the charge switching unit is de-energized and the stand timer (0 to 150 min.) is started. When the stand timer has timed out, a step signal is sent to the sequence stepper which moves the stepper to position #3. Thus the discharge switching unit is energized, connecting the constant current discharge regulator (2. 6A) and the series discharge supply to the series connected cells in such a manner that the cells are discharged at the 2. 6 amp. rate. During the discharge step, as well as the charge and stand steps, the cell voltages and current are monitored and recorded by the data logger. When any particular cell reaches a discharge voltage of 1. 0 volt a coincidence or "and", signal is sensed by the corresponding "and" gate, and a cell cutout command is issued to the corresponding output switching unit. When all ten cells have discharged to 1. 0 volt, the cell cutout counter issues a "10 cells disconnected" signal to the sequence stepper which moves to position #4. At position #4 the charge half-cycle is again repeated. This sequence of operation is continued until a total of three charge-stand-discharge cycles have been performed. The only exception being that at the beginning of the third and final discharge, a group of 10 elapsed time meters are started. Each time meter is associated with a particular cell and measures the elapsed time between the start of the third discharge and the point at which the corresponding cell reaches 1. 0 volt. Thus by later multiplying the constant current discharge value (2. 6 amps) and the time indicated by the elapsed time meter, the capacity of a cell, in ampere-minutes, may be obtained.

This unit is equipped with an overvoltage switch which automatically disconnects the charge circuit from the cells in the event that the constant current charging rate of 0. 6 amps. causes any of the cells to reach 1. 50 volts.



Capacity Test Unit
and Data Logger

FIGURE 6

CAPACITY TEST UNIT FUNCTIONAL BLOCK DIAGRAM

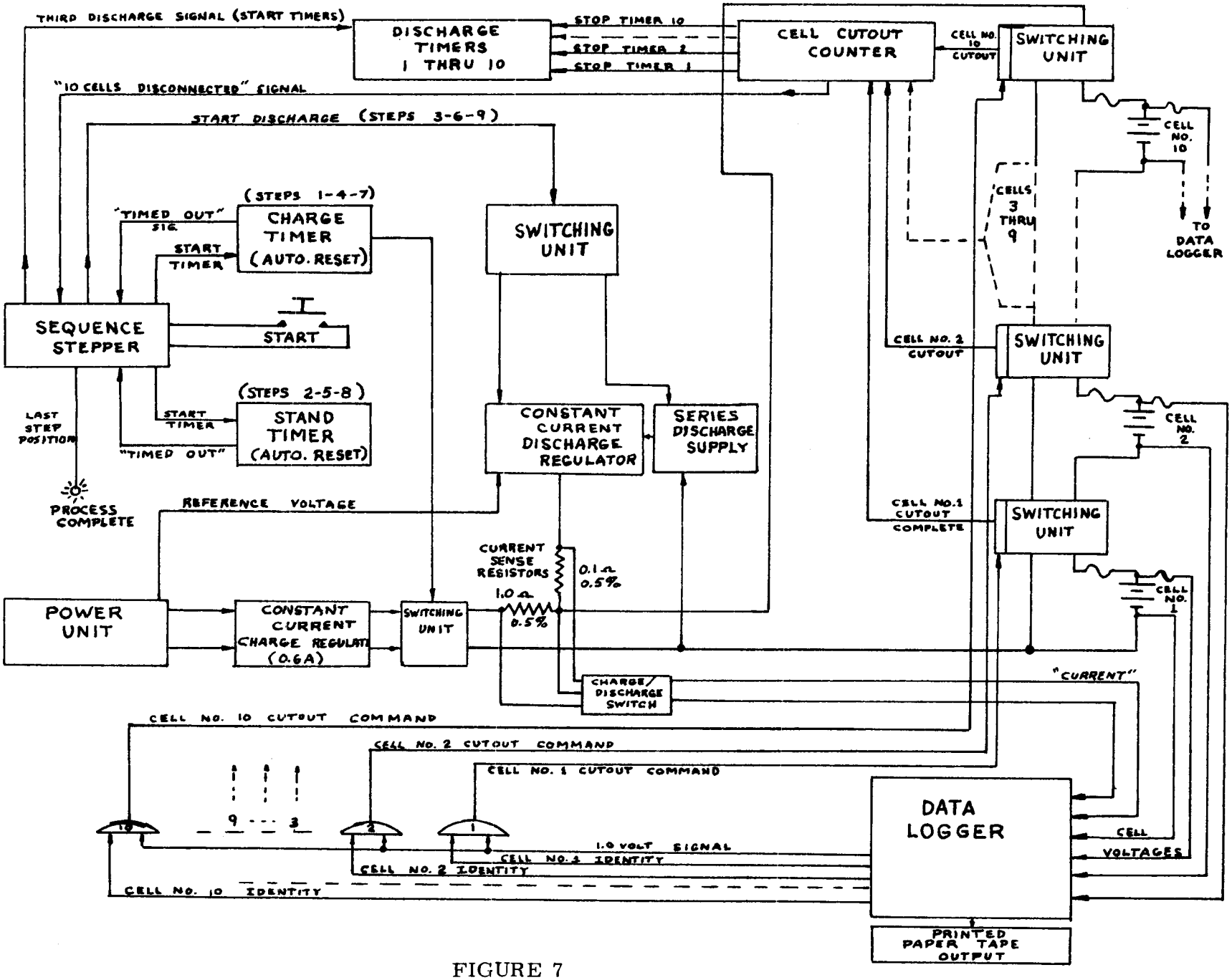


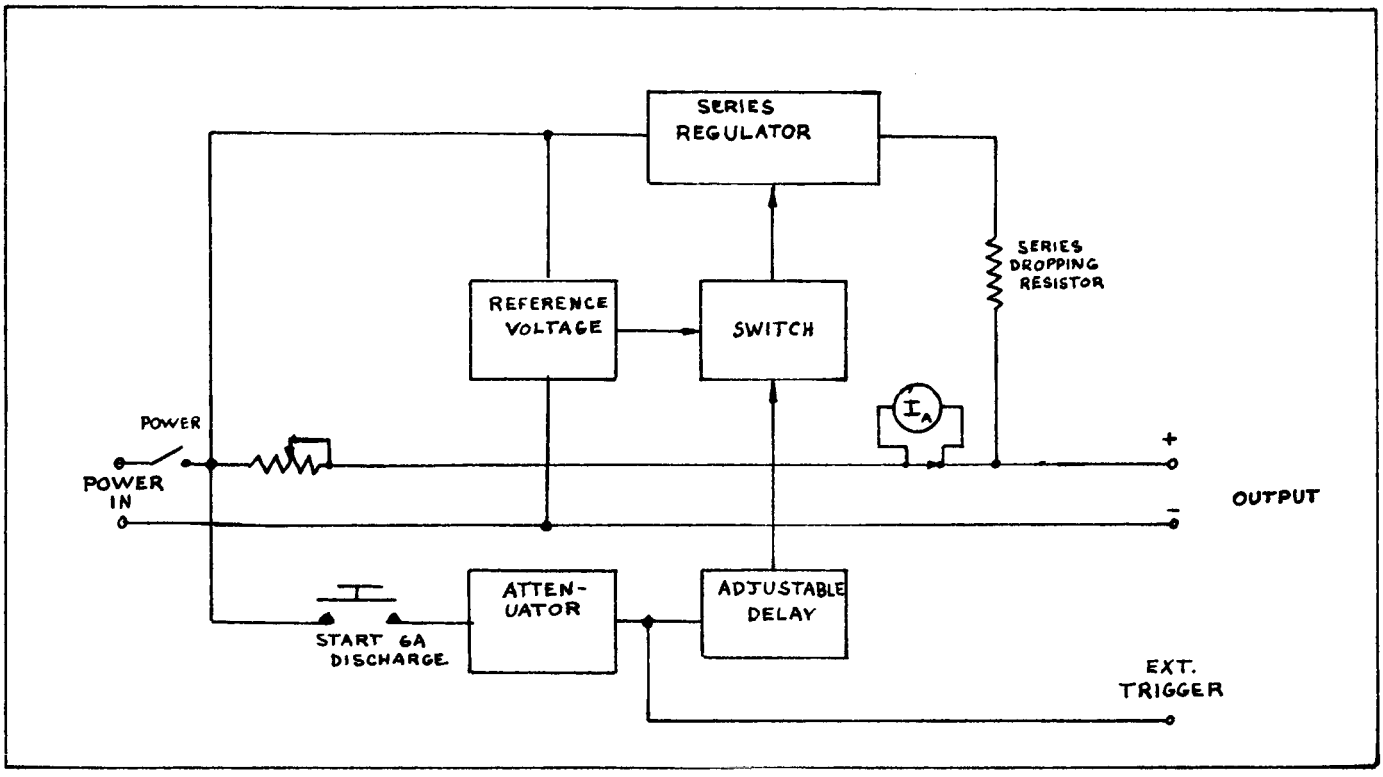
FIGURE 7

2. 2. 3 Internal Resistance Test Unit and Test Set-up

The following description is made with reference to the Internal Resistance Test Unit Functional Block Diagram, Figure 8.

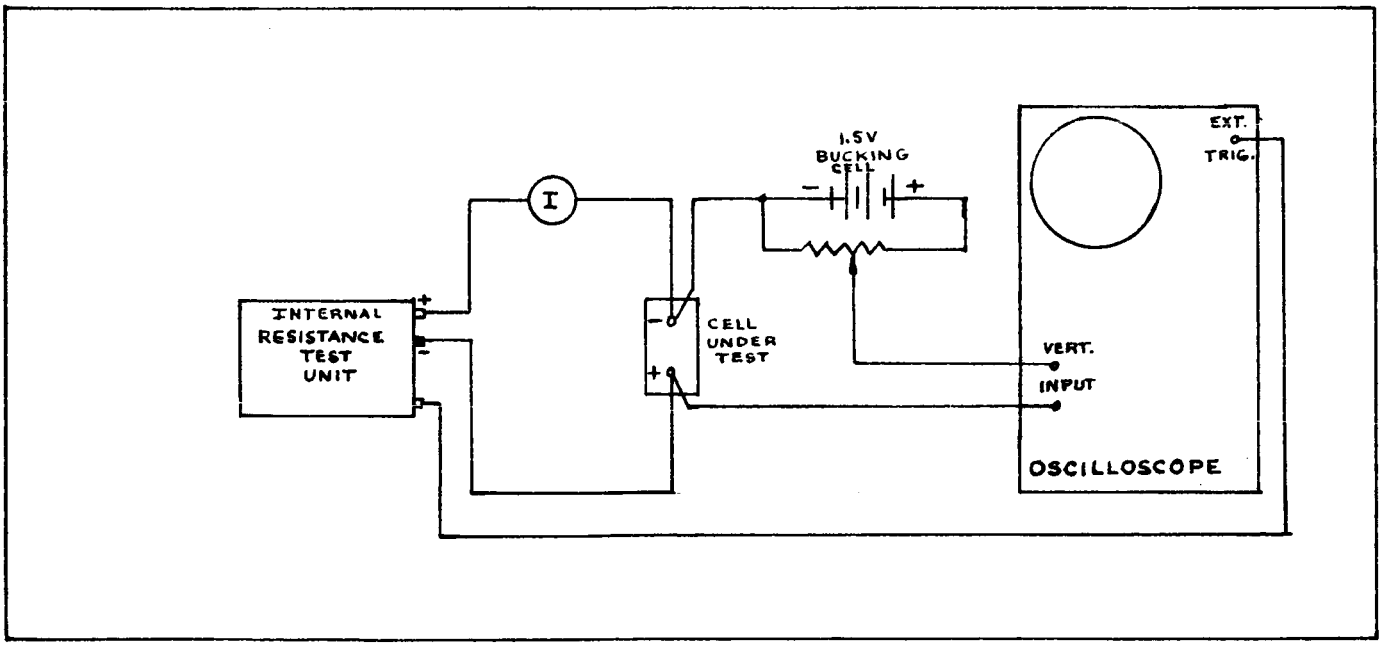
When connected to the test set-up shown in figure 9, turning on the Power switch starts the 0. 3A cell discharge which is metered with I_A. After the cell voltage has stabilized (approximately 5 minutes) as indicated by the oscilloscope trace, the "Start 6A Discharge" switch is depressed by the operator. This action applies a positive pulse to the scope external trigger jack and starts the trace moving across the CRT. The same pulse that starts the scope trace starts an adjustable delay. After the delay period a reference voltage is switched to the normally cutoff series regulator and thus starts the 6 amp. discharge (the actual current in this loop is 5. 7 amps which is added to the original 0. 3 amps to produce 6. 0 amps.)

The delay period mentioned above is adjusted so that with a scope sweep of 5 ms/cm, the 6 amp pulse is applied to the cell when the trace is in the approximate center of the CRT face. A camera attached to the CRT face with the shutter open records the entire event.



INTERNAL RESISTANCE TEST UNIT
FUNCTIONAL BLOCK DIAGRAM

FIGURE 8



INTERNAL RESISTANCE TEST SET-UP

FIGURE 9

3.0 Test Results

A total of 239 cells were furnished by the government. Cell shipments were as follows:

162 cells	May 1963
69 cells	August 1963
8 cells	September 1963

The last group of 8 cells were equipped with pressure transducers.

Acceptance Testing was started on May 27, 1963 and completed on September 24, 1963. Additional testing on approximately 12 pressure transducer equipped cells is expected to start in the near future. Results of acceptance testing on these additional cells will be furnished in a supplemental report.

All of the cells tested were of the same type, from the same manufacturer, and had the same nominal capacity of 6 ampere-hours.

Detailed results of each test are listed below.

3.1 Phenolphthalein Leak Test

Following the conditioning process each cell was tested for caustic leaks using a neutral phenolphthalein solution. Of the 239 cells tested, 10 cells were found with small leaks. These cells are listed below.

MFGS SERIAL NO.	CONTRACTORS ASSIGNED CELL NUMBER	LOCATION OF LEAK
2863	12	+ Terminal
2873	45	+ Terminal
2876	55	+ Terminal
2850	58	near - Terminal
2839	76	+ Terminal
3146	84	+ Terminal
2833	104	+ Terminal
2406	237	press. tube mount
2527	238	+ Terminal
2183B	142	+ Terminal

3. 2 Capacity Test

3. 2. 1 Capacity

The capacity values for all cells passing acceptance testing are listed in Table 1, List of Measured Capacity Values. Capacity values are also listed for some cells which failed the acceptance test. These include cell failures that occurred after capacity testing, certain "overvoltage" cells (described in para. 3. 2. 2) which were under further investigation, and cells with caustic leaks. All cells numbers with an "F" prefix failed the acceptance test. A suffix letter following the cell number indicates the type of failure:

S_____shorted internally
X_____overvoltage on charge
L_____caustic leak
G_____blocked pressure gauge

Graph No. 1, Capacity Distribution Graph, illustrates the distribution pattern of all initially accepted cells (no failed cells are included). The average capacity of these 133 initially accepted cells is 6. 340 ampere-hours. (See para. 3. 5 Cell Selection).

TABLE 1

LIST OF MEASURED CAPACITY VALUES

Mfgs. Cell Serial No.	Test Cell No.	Ampere-Hour Capacity	Mfgs. Cell Serial No.	Test Cell No.	Ampere-Hour Capacity
2869	001	5.943	3117	37	6.257
2874	002	6.104	3153	38	6.239
2858	003	6.213	3110	39	5.956
2854	004	6.170	2867	40	6.327
2852	005	6.301	3155	41	6.187
2887	006	6.253	3154	42	6.148
2870	007	6.248	2862	43	6.060
2884	008	6.484	3114	44	6.030
2851	009	6.178	2873	F45L	6.069
2853	010	6.344	3141	46	6.279
3145	011	6.218	3125	47	6.418
2863	F012L	6.235	3148	49	6.266
2856	F013G	6.419	3162	50	5.969
2882	014	6.322	3156	51	5.960
3129	015	6.480	3116	52	6.549
3142	016	6.580	2861	53	6.410
3151	017	6.322	3112	54	6.248
3149	018	6.606	2876	F55L	6.440
2872	019	6.296	3144	56	6.143
3130	020	6.497	3113	57	6.423
2871	021	6.209	2850	F58L	6.222
3124	022	6.868	3108	59	6.418
2865	023	6.589	3160	60	6.117
3120	024	6.418	2881	62	6.440
2886	025	6.113	3158	63	6.279
3131	026	6.453	2831	64	6.209
2878	027	6.453	2848	65	6.301
2888	028	6.414	2866	66	6.113
3109	029	6.052	3123	67	6.248
3139	030	6.279	2826	68	6.432
2879	031	6.327	3127	F69S	6.619
3159	032	6.056	2825	70	6.174
2860	033	6.484	2838	71	6.182
3118	034	6.384	3164	72	6.331
3128	035	5.995	2836	73	6.235
3126	036	6.152	2877	74	6.584

Mfgs. Cell Serial No.	Test Cell No.	Ampere-Hour Capacity	Mfgs. Cell Serial No.	Test Cell No.	Ampere-Hour Capacity
2829	75	6.104	2931	196	6.650
2839	F76L	6.196	2926	197	6.152
3165	78	6.602	2929	198	6.269
2841	79	6.349	2896	200	6.423
3143	80	6.135	2891	201	6.794
3121	82	6.785	2927	202	5.991
3166	85	6.436	2902	203	6.528
2846	86	6.475	2904	F204S	6.205
2842	88	6.519	2911	205	6.143
2828	89	6.397	2895	206	6.340
2855	90	6.401	2924	207	5.855
3161	91	6.130	2907	208	6.515
2845	92	6.174	2934	209	6.065
2837	93	6.231	2928	210	6.004
2827	94	6.405	2922	211	6.235
2830	95	6.314	2930	212	6.506
3132	96	6.331	2932	213	6.366
2880	97	6.462	2914	214	6.475
3111	98	6.794	2935	215	6.100
3150	99	6.370	2910	216	6.349
3115	100	6.672	2890	217	6.646
2868	102	6.056	2906	218	6.480
2840	103	6.274	2900	219	6.833
2883	F104L	6.135	2923	F220S	6.405
2835	105	6.183	2912	221	6.471
3119	106	6.523	2901	222	7.012
3458	107	6.392	2892	223	6.842
2849	108	6.148	2905	224	6.353
2832	109	6.239	2899	225	6.375
2883	110	6.392	2920	226	6.060
2847	111	6.488	2916	227	6.445
3457	F112G	6.646	2908	228	6.309
3122	115	6.510	2909	229	6.549
2834	120	6.558	2893	230	6.654
2894	193	6.506	2919	231	6.287
2925	194	6.715			
2898	195	6.318			

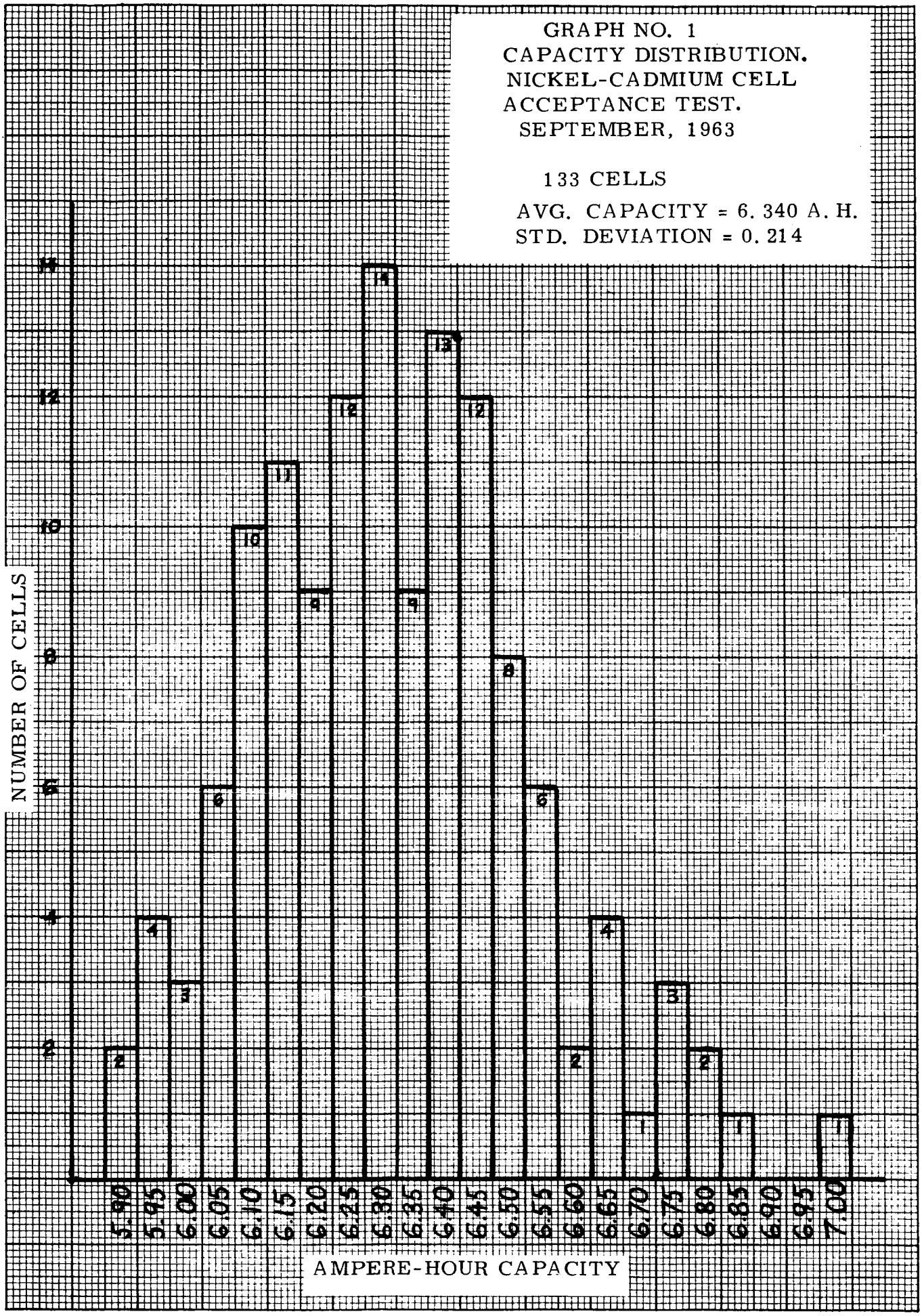
Legend

PREFIX

F - Failed Cell

SUFFIX

S——Shorted cell
X——Overvoltage on charge
L——Caustic Leak
G——Blocked pressure gauge


GRAPH NO. 1
CAPACITY DISTRIBUTION.
NICKEL-CADMIUM CELL
ACCEPTANCE TEST.
SEPTEMBER, 1963
133 CELLS
AVG. CAPACITY = 6.340 A. H.
STD. DEVIATION = 0.214
NUMBER OF CELLS
AMPERE-HOUR CAPACITY
5.90
5.95
6.00
6.05
6.10
6.15
6.20
6.25
6.30
6.35
6.40
6.45
6.50
6.55
6.60
6.65
6.70
6.75
6.80
6.85
6.90
6.95
7.00

3.2.2 Terminal Voltages

The end charging voltage of each initially accepted cell is listed in Table 2, Terminal Charging Voltages. Terminal voltages are also listed for failed cells where applicable.

The possibility of a significant difference in terminal voltages between charge no. 1 and charges no. 2 and 3 is apparent from a glance at Table 2. This possibility has been computed and found to be approximately 97 percent, that is, there is a 97 percent possibility that the terminal voltages of charge no. 1 is significantly different from charges 2 and 3. Computed results also indicate that the possibility of a significant change between the terminal voltages of charges 2 and 3 is very close to 0.

The average of all the initially accepted cells for charges 1, 2 and 3 are as follows:

Charge No. 1	1.444 volts
Charge No. 2	1.425 volts
Charge No. 3	1.420 volts

The 0.024 volt spread of these averages is most probably due to the dissimilar initial conditions between charge no. 1 and charges no. 2 and 3: charge no. 1 was applied to cells which had been previously short circuited for 16 hours, and charges no. 2 and 3 were applied to cells which had been discharged to 1.0 volts. The conclusions drawn above have been corroborated by the results of additional testing where a group of 10 cells was charged with varying initial conditions.

TABLE 2

Terminal Charging Voltages

Test Cell No.		01	02	03	04	05	06	07	08	09	10	
Chg.	1	1.46	1.44	1.44	1.45	1.45	1.44	1.46	1.44	1.45	1.45	volts
	2	1.42	1.42	1.43	1.41	1.42	1.42	1.42	1.42	1.41	1.42	
	3	1.42	1.41	1.41	1.42	1.42	1.41	1.42	1.41	1.41	1.42	
Cell		11	F12L	F13G	14	15	16	17	18	19	20	
Chg.	1	1.43	1.44	1.44	1.43	1.44	1.44	1.43	1.44	1.44	1.43	
	2	1.41	1.42	1.42	1.40	1.43	1.42	1.41	1.42	1.42	1.41	
	3	1.42	1.42	1.40	1.41	1.42	1.41	1.42	1.42	1.40	1.43	
Cell		21	22	23	24	25	26	27	28	29	30	
Chg.	1	1.43	1.45	1.45	1.43	1.43	1.45	1.44	1.43	1.45	1.44	
	2	1.42	1.43	1.41	1.43	1.40	1.41	1.42	1.42	1.41	1.43	
	3	1.42	1.43	1.40	1.42	1.40	1.41	1.42	1.41	1.41	1.43	
Cell		31	32	33	34	35	36	37	38	39	40	
Chg.	1	1.44	1.44	1.44	1.44	1.45	1.45	1.44	1.44	1.45	1.44	
	2	1.42	1.41	1.42	1.44	1.41	1.43	1.43	1.41	1.43	1.43	
	3	1.41	1.40	1.42	1.43	1.41	1.43	1.43	1.40	1.43	1.41	
Cell		41	42	43	44	F45L	46	47	F48X	49	50	
Chg.	1	1.45	1.45	1.45	1.45	1.45	1.46	1.46	---	1.45	145	
	2	1.43	1.43	1.43	1.43	1.43	1.44	1.44	---	1.43	1.42	
	3	1.43	1.42	1.42	1.43	1.42	1.42	1.42	---	1.43	1.42	
Cell		51	52	53	54	F55L	56	57	F58L	59	60	
Chg.	1	1.43	1.43	1.44	1.44	1.43	1.45	1.44	1.43	1.45	1.44	
	2	1.41	1.43	1.42	1.41	1.42	1.42	1.41	1.43	1.44	1.41	
	3	1.40	1.43	1.41	1.41	1.41	1.42	1.41	1.42	1.43	1.40	
Cell		F61X	62	63	64	65	66	67	68	F69S	70	
Chg.	1	---	1.43	1.43	1.43	1.42	1.44	1.44	1.43	1.43	1.43	
	2	---	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.45	1.43	
	3	---	1.42	1.42	1.42	1.42	1.43	1.43	1.42	1.45	1.42	

TABLE 2 (continued)

Cell		71	72	73	74	75	F76LS	F77X	78	79	80
Chg.	1	1.45	1.46	1.44	1.44	1.45	1.45	---	1.45	1.45	1.46
	2	1.43	1.44	1.42	1.43	1.42	1.43	---	1.43	1.42	1.43
	3	1.42	1.43	1.42	1.42	1.42	1.42	---	1.43	1.42	1.42

Cell		F81X	82	F83X	F84L	85	86	F87S	88	89	90
Chg.	1	---	1.45	---	1.46	1.44	1.45	1.45	1.44	1.44	1.45
	2	---	1.44	---	1.43	1.43	1.44	1.43	1.43	1.43	1.44
	3	---	1.43	---	1.44	1.43	1.43	1.43	1.42	1.42	1.43

Cell		91	92	93	94	95	96	979	98	99	100
Chg.	1	1.45	1.45	1.45	1.45	1.45	1.46	1.45	1.45	1.44	1.45
	2	1.42	1.42	1.42	1.41	1.42	1.44	1.42	1.42	1.43	1.42
	3	1.43	1.42	1.42	1.42	1.42	1.43	1.42	1.43	1.42	1.43

Cell		F101X	102	103F	104L	105	106	107	108	109	110
Chg.	1	---	1.45	1.44	1.44	1.44	1.45	1.44	1.44	1.44	1.44
	2	---	1.43	1.42	1.42	1.42	1.43	1.42	1.43	1.42	1.43
	3	---	1.43	1.42	1.41	1.42	1.43	1.42	1.42	1.42	1.43

Cell		111	F112G	F113X	F114X	115	F116X	F117X	F118X	F119X	120
Chg.	1	1.44	1.44	---	---	1.45	---	---	---	---	1.44
	2	1.42	1.43	---	---	1.43	---	---	---	---	1.43
	3	1.42	1.42	---	---	1.43	---	---	---	---	1.42

Cell F121X through F192X

Cell		193	194	195	196	197	198	F199T	200
Chg.	1	1.44	1.45	1.44	1.45	1.44	1.45	---	1.45
	2	1.42	1.43	1.42	1.43	1.42	1.43	---	1.43
	3	1.42	1.42	1.42	1.42	1.42	1.42	---	1.42

Cell		201	202	203	F204S	205	206	207	208	209	210
Chg.	1	1.45	1.45	1.45	1.45	1.45	1.45	1.44	1.45	1.45	1.44
	2	1.43	1.43	1.42	1.43	1.42	1.43	1.42	1.43	1.43	1.42
	3	1.43	1.42	1.42	1.43	1.42	1.42	1.42	1.42	1.42	1.42

TABLE 2 (continued)

Cell		211	212	213	214	215	216	217	218	219	F220S
Chg.	1	145	145	145	144	145	145	145	145	145	145
	2	143	143	143	143	143	143	143	143	143	143
	3	142	142	142	142	142	142	142	142	142	142
Cell		221	222	223	224	225	226	227	228	229	230
Chg.	1	145	145	145	145	144	146	145	145	145	145
	2	143	143	143	143	143	143	143	143	143	143
	3	142	142	142	142	142	142	143	142	142	142
Cell		231									
Chg.	1	145									
	2	143									
	3	142									

LEGEND

PREFIX

F _____ Failed cell

SUFFIX

S _____ Shorted cell
X _____ Overvoltage on charge
L _____ Caustic leak
T _____ Malformed terminal
G _____ Blocked gauge

3. 2. 2 Terminal Voltage (continued)

Approximately 35 percent of all cells tested exhibited an overvoltage condition when charged at a 0. 60 ampere rate. These cells reached a closed circuit voltage of 1. 50 volts in less than 16 hours, usually in 11 to 14 hours, and most probably would have gone higher had they not been disconnected from the charging source upon reaching 1. 50 volts. Graph No. 2, Normal vs "Overvoltage" cell charge characteristics, illustrates the increase in terminal voltage on one of these cells as compared to a "normal"cell .

This characteristic of some cells, although previously observed by the cell manufacturer, was peculiar in that it occurred only in cells with a certain type of pressure gauge. All normal cells were equipped with a Marsh Instrument Co. gauge or no gauge at all, and all overvoltage cells were equipped with a gauge manufactured by U. S. Gauge Co. The 100 percent failure rate of the cells equipped with the latter gauge was too great to consider the results coincidental; yet, the cause of the overvoltage characteristic could not be readily attributed to the gauge itself because of the similarity of two gauges, both in construction and method of operation. Although the latter gauge was physically larger than the other gauge, 2 3/4 inches O. D. as compared to 2 1/4 inches O. D. , the internal volume of the two gauges was identical: 2. 0 cc. The only other difference noted was a very slight white and green flecked corrosive appearing film found on the inside of the entrance fitting on each of the two U. S. Gauge Co. gauges inspected.

Preliminary investigation disclosed that several different manufacturing lot numbers were represented in the group of failed cells. This fact seemed to rule out the possibility of a manufacturing process defect in a certain batch or lot of cells.

3. 2. 2 (continued)

At the present time investigation is being continued on the previously mentioned corrosion found in the gauge fitting. A supplemental report on the findings of these tests will be presented upon test completion.

A computer programmed "Least Squares Polynomial Fit" routine on the two characteristic curves in Graph No. 2, page III-12, yielded the following equations:

Curve No. 1, "Normal Cell"
lst order fit

$$Y = 1.335 + .00694\,X$$
and Std. Deviation = .0112 volts

where Y = Cell Voltage
and X = Hours of charge at 0.600 amps.

Curve No. 2, "Overvoltage Cell"
lst order fit

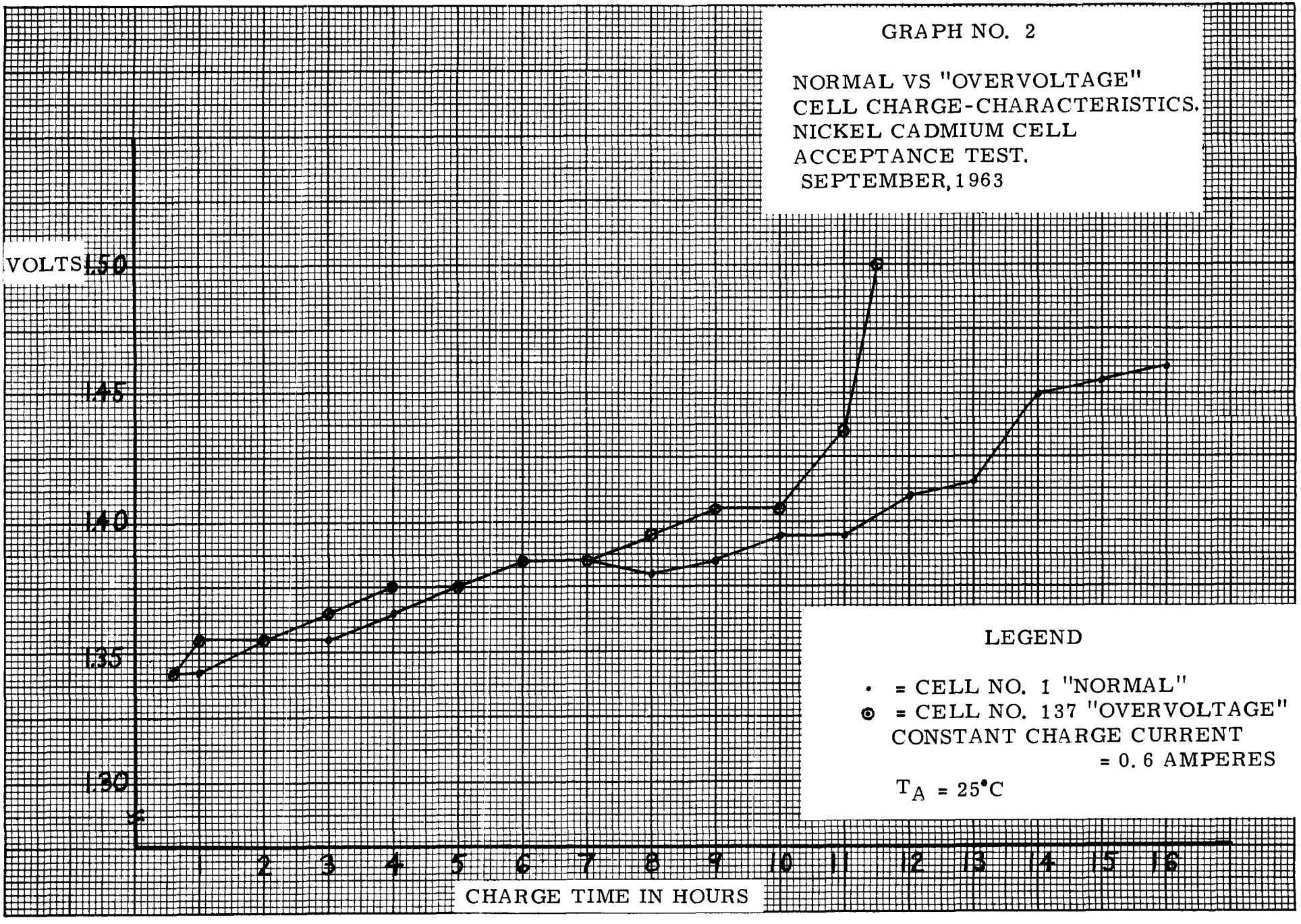
$$Y = 1.333 + .00966\,X$$
and Std. Deviation = .0162 volts

3rd order fit

$$Y = 1.329 + .0266X - .00519X^2 + .000348X^3$$
and Std. Deviation = .0102 volts

GRAPH NO. 2

NORMAL VS "OVERVOLTAGE"
CELL CHARGE-CHARACTERISTICS.
NICKEL CADMIUM CELL
ACCEPTANCE TEST.
SEPTEMBER, 1963



LEGEND

• = CELL NO. 1 "NORMAL"
⊙ = CELL NO. 137 "OVERVOLTAGE"
CONSTANT CHARGE CURRENT
= 0.6 AMPERES

T_A = 25°C

3. 2. 3 Pressure

Terminal Pressure readings for all cells equipped with pressure gauges are listed in Table 3. Readings labeled CHG 1 TERM, CHG 2 TERM and CHG 3 TERM represent cell pressures recorded at the termination of capacity test charges No. 1, No. 2 and No. 3, respectively. All negative readings are in Inches of Mercury and all positive readings are in Pounds per Square Inch.

The list of third charge pressure readings for cells 001 through 010 is representative of the readings taken for all normal cells during the third charge. All cells, with the exception of those with blocked pressure gauges, exhibited similar patterns of pressure movement during the third charge half-cycle of the capacity test. Since cell pressures did not change appreciably during the first 10 hours of charge, only the readings taken during the last 6 hours of charge were recorded.

In practically all cases a significant change in terminal pressure was noted between charge No. 1 and charges No. 2 and 3. The difference in initial charge conditions, mentioned in para. 3. 2. 2, was most probably the cause of this increasing pressure with increasing charge number.

A wide distribution in charge No. 3 terminal pressures is illustrated in the Terminal Pressure Distribution Graph, Graph No. 3. It should be noted, however, that initial pressure readings, those taken at the beginning of the third charge, varied from cell to cell by as much as 14 inches of Mercury. Typical pressure-charge characteristics for three cells, No's 1, 5 and 19 are illustrated in Graph No. 4.

Table 3

Capacity Test Pressure Readings

Typical Capacity Test Pressure Data							Cell Numbers 001 to 010			
001	002	003	004	005	006	007	008	009	010	Time
+04	-10	+00	+01	+00	+01	-01	-11	+00	-00	Chg. 1 Term.
+09	-08	+03	+05	+04	+07	+05	-09	+04	+03	Chg. 2 Term.
-18	-25	-19	-18	-24	-22	-20	-30	-20	-20	10-1
-18	-24	-18	-16	-21	-20	-20	-25	-20	-20	10-2
-17	-22	-16	-16	-20	-20	-20	-25	-20	-20	10-3
-16	-22	-17	-16	-19	-18	-18	-22	-18	-18	10-4
-15	-21	-16	-16	-19	-18	-18	-21	-18	-18	11-1
-15	-20	-16	-15	-20	-16	-16	-17	-17	-20	11-2
-14	-14	-15	-15	-20	-16	-16	-20	-16	-20	11-3
-14	-14	-16	-15	-18	-15	-15	-20	-15	-18	11-4
-10	-18	-13	-12	-16	-14	-15	-19	-15	-15	12-1
-10	-16	-14	-10	-15	-12	-15	-20	-15	-15	12-2
-07	-16	-14	-15	-15	-10	-14	-20	-17	-15	12-3
-04	-15	-10	-08	-15	-09	-12	-18	-10	-14	12-4
+00	-15	-10	-05	-15	-07	-10	-17	-10	-10	13-1
+03	-10	-05	-03	-10	-05	-07	-15	-05	-10	13-2
+00	-10	+03	-05	-05	-03	-05	-15	-03	-05	13-3
+06	-10	+00	-05	-02	+00	-04	-15	+00	-05	13-4
+06	-06	+00	-03	-05	+01	+00	-12	+01	-05	14-1
+08	-05	+01	+00	-03	+03	-01	-10	+03	+00	14-2
+09	-05	+03	+00	+00	+03	+02	-10	+03	-03	14-3
+09	-02	-03	+03	+03	+03	+03	-07	+06	+03	14-4
+09	-01	+01	+01	+00	+06	+03	-05	+06	+00	15-1
+09	+00	+03	+03	+03	+06	+03	-05	+06	+03	15-2
+09	+00	+06	+06	+03	+07	+03	-02	+06	+03	15-3
+09	+00	+06	+06	+03	+07	+05	-01	+06	+03	15-4
+10	+00	+04	+06	+04	+08	+05	-03	+05	+04	16-1
+11	+00	+05	+05	+04	+08	+05	-02	+05	+04	16-2
+11	+00	+05	+05	+04	+08	+05	-01	+06	+04	16-3
+11	+00	+05	+05	+04	+08	+06	-01	+06	+04	Chg. 3 Term.

			Cell Numbers 11 to 20							
011	F012L	F013G	014	015	016	017	018	019	020	Time
+00	+01	-25	-09	+01	-05	+00	+02	+03	+00	Chg. 1 Term.
+03	+05	-25	-05	+03	+00	+02	+04	+06	+00	Chg. 2 Term.
+04	+06	-25	-01	+03	+02	+03	+05	+08	+01	Chg. 3 Term.

Table 3 (continued)

					Cell Numbers 21 to 30					
021	022	023	024	025	026	027	028	029	030	Time
-02	+03	-09	+02	+01	+03	-09	-05	+13	+00	Chg. 1 Term
+01	+13	+00	+05	+03	+05	-04	+00	+16	+02	Chg. 2 Term
+02	+14	+00	+06	+04	+05	-01	+01	+17	+03	Chg. 3 Term
					Cell Numbers 31 to 40					
031	032	033	034	035	036	037	038	039	040	
-07	+03	-09	+03	+15	+15	+06	+00	+08	-03	Chg. 1 Term
-05	+06	-05	+06	+22	+21	+08	+01	+13	+03	Chg. 2 Term
-01	+09	-05	+06	+24	+22	+12	+02	+15	+04	Chg. 3 Term
					Cell Numbers 41 to 50					
041	042	043	044	F045L	046	047	F048L	049	050	
+05	+02	-05	+11	-05	-05	+05	---	+00	-05	Chg. 1 Term
+07	+09	+01	+15	+01	+01	+09	---	+01	+00	Chg. 2 Term
+08	+10	+02	+17	+02	+02	+10	---	+03	+02	Chg. 3 Term
					Cell Numbers 51 to 60					
051	052	053	054	F055L	056	057	F058L	059	060	
+01	+01	-06	+07	-10	+00	+01	-08	+06	+00	Chg. 1 Term
+04	+04	+01	+12	-05	+03	+04	+04	+11	+01	Chg. 2 Term
+04	+05	+02	+15	+00	+02	+04	+07	+12	+02	Chg. 3 Term
					Cell Numbers 61 to 70					
F061X	062	063	064	065	066	067	068	F069S		070
-12	-20	-12	-26	-25	-20	-17	-22	-25	-15	Chg. 1 Term
+08	+06	+12	+06	+03	+19	+16	+05	+02	+06	Chg. 2 Term
---	+12	+15	+12	+05	+26	+18	+10	+03	+08	Chg. 3 Term
					Cell Numbers 71 to 80					
071	072	073	074	074	F076L	F077X	078	078	080	
-20	-15	-17	-20	-20	-22	+02	-17	-20	-05	Chg. 1 Term
---	+13	+07	+04	+06	+03	---	+04	+05	+17	Chg. 2 Term
---	+15	+08	+06	+09	+04	---	+05	+06	+19	Chg. 3 Term

Table 3 (continued)

Cell Numbers 81 to 90

F081X	082	F083X	F084L	085	086	F087S	088	089	090	
---	+12	---	---	+04	+05	---	-07	+02	+12	Chg 1 Term
---	+20	---	---	+09	+09	---	-03	+10	+20	Chg 2 Term
---	+24	---	---	+12	+13	---	+06	+13	+22	Chg 3 Term

Cell Numbers 91 to 100

091	092	093	094	095	096	097	098	099	100	
+15	+12	-06	+02	+00	+13	+06	-05	+04	-04	Chg 1 Term
---	---	---	---	---	---	---	---	---	---	Chg 2 Term
+27	+16	+01	+07	+04	+25	+13	+02	+07	+02	Chg 3 Term

Cell Numbers 101 to 110

F101X	102	103	F104L	105	106	107	108	109	110	
---	+16	-10	+00	+00	+02	+03	+00	+04	+05	Chg 1 Term
---	+26	+02	+05	+03	+07	+04	+02	+12	+09	Chg 2 Term
---	+28	+03	+06	+03	+09	+05	+03	+12	+09	Chg 3 Term

Cell Numbers 111 to 120

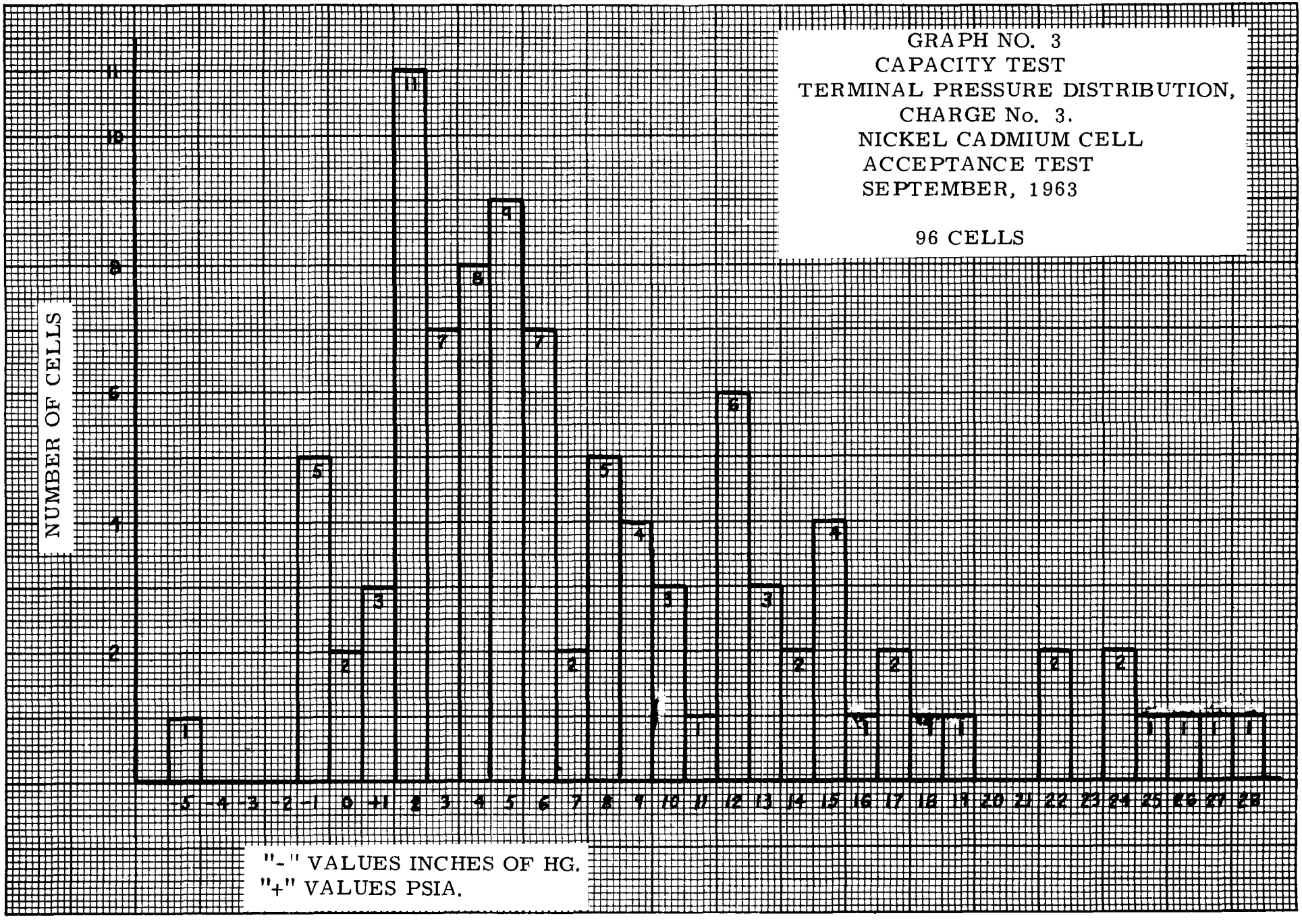
111	F112G	F113X	F114X	115	F116X	F117X	F118X	F119X	120	
-15	-30	---	---	+00	---	---	---	---	-12	Chg 1 Term
-07	-30			+06					-04	Chg 2 Term
-01	-30	---	---	+14	---				+05	

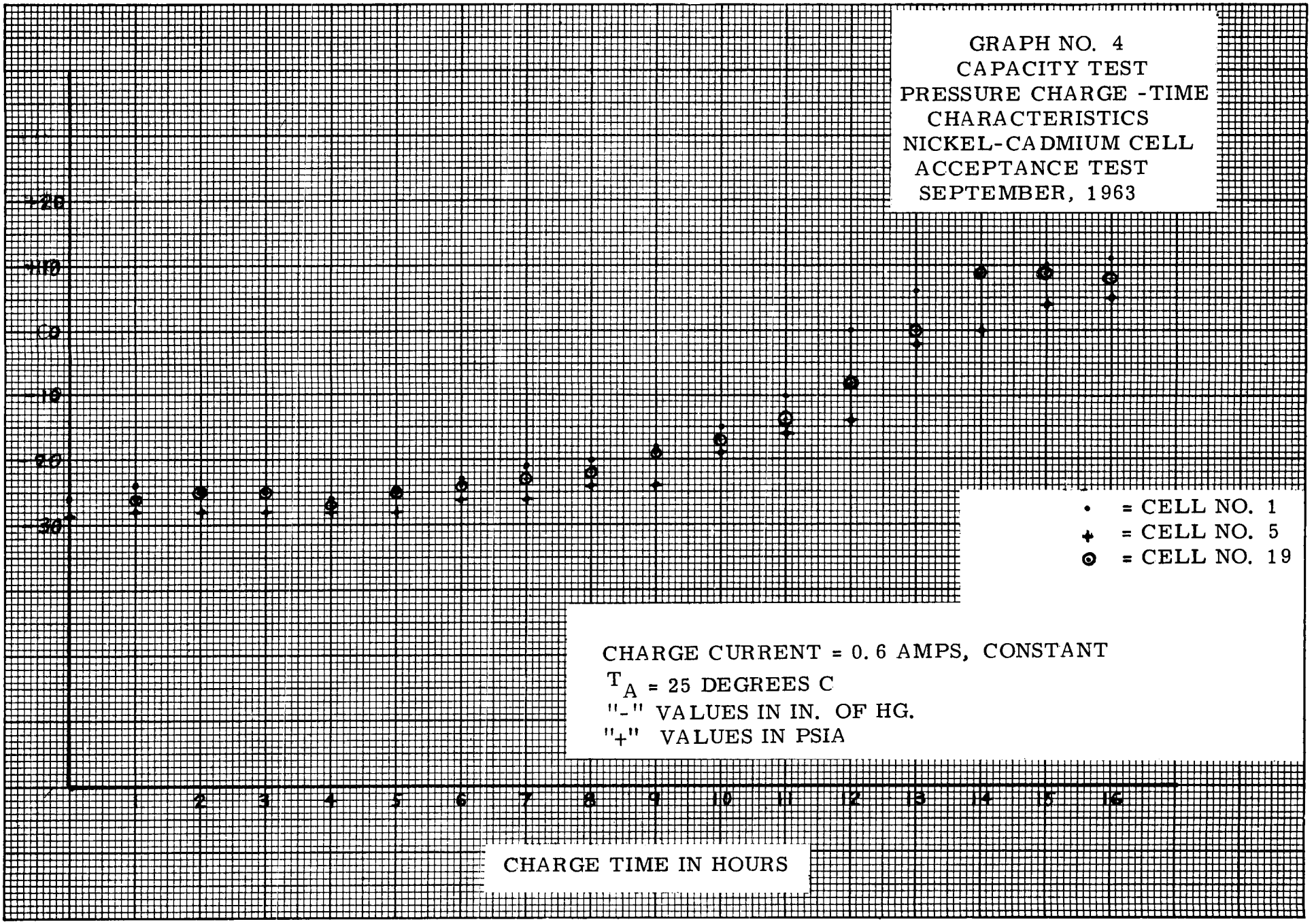
All remaining cells either failed acceptance tests or were not equipped with pressure gauges.

Legend

Prefix F_____ failed cell
Suffix S_____ internal short
X_____ overvoltage
L_____ caustic leak
G_____ blocked gauge

"-" values in in. of Hg.
"+" values in PSIA


GRAPH NO. 3
CAPACITY TEST
TERMINAL PRESSURE DISTRIBUTION,
CHARGE No. 3.
NICKEL CADMIUM CELL
ACCEPTANCE TEST
SEPTEMBER, 1963
96 CELLS
NUMBER OF CELLS
"-" VALUES INCHES OF HG.
"+" VALUES PSIA.


GRAPH NO. 4
CAPACITY TEST
PRESSURE CHARGE -TIME
CHARACTERISTICS
NICKEL-CADMIUM CELL
ACCEPTANCE TEST
SEPTEMBER, 1963
+20
+10
0
-10
-20
-30
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
• = CELL NO. 1
+ = CELL NO. 5
⊙ = CELL NO. 19
CHARGE CURRENT = 0.6 AMPS, CONSTANT
T_A = 25 DEGREES C
"-" VALUES IN IN. OF HG.
"+" VALUES IN PSIA
CHARGE TIME IN HOURS

3.3 Cell Short Test

Nine cells were rejected because of internal short circuits. These cells are listed below with their open circuit voltage after the specified 24 hour stand period. It is interesting to note that most of these internally shorted cells appeared normal in other respects such as ampere-hour capacity, internal pressure and terminal voltage.

MFG'S SERIAL NO.	CONTRACTORS ASSIGNED CELL NUMBER	CELL VOLTAGE. VOLTS
3127	69	0.984
2839	76	0.375
2844	87	0.760
2094	130	0.767
2110	135	0.734
2130	170	0.621
2132	174	0.220
2904	204	0.054
2923	220	0.845

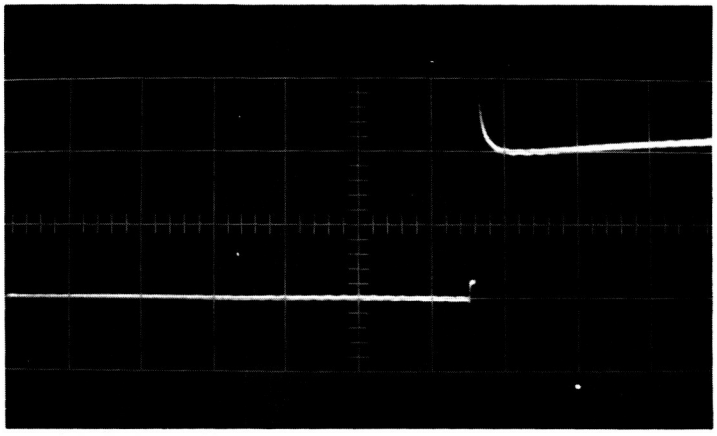
3.4 Internal Resistance

Figure 10 is a photograph of the CRT display of a cell voltage as the cell was subjected to the internal resistance test. The left hand portion (6.5 cm) of the trace, represents the cell voltage under 0.3 amp discharge and the right hand portion. represents the cell voltage action during 6 amp discharge. The increase in voltage level displayed in the photograph is caused by the net resultant of the positive bucking cell voltage, which is constant, and the decreasing nickel-cadmium cell voltage as it is subjected to the 6 amp. discharge. (see Figure 9). All cells tested exhibited a waveform similar to the one shown in Figure 10.

During the first two or three milliseconds after application of the 6 amp discharge pulse, cell voltages decreased very rapidly and then recovered exponentionally to about the half-way point of the first excursion. During the remainder of the scope trace period all cell voltages displayed an average decay of approximately 5 millivolts.

Figure 11 shows a photograph of the CRT display with a Weston shunt (50 MV/amp) connected in place of the nickel-cadmium cell. The first portion of the trace, after 6 amp. discharge initiation, shows a transient current pulse approximately 200 u sec. wide, caused by switch-in action of the reference supply in the Internal Resistance Test Unit. The difference in the voltage levels between the left and right hand portions of the trace is 280 millivolts which can be expressed as a change in current of 5.6 amps (0.3 amps to 5.9 amps)

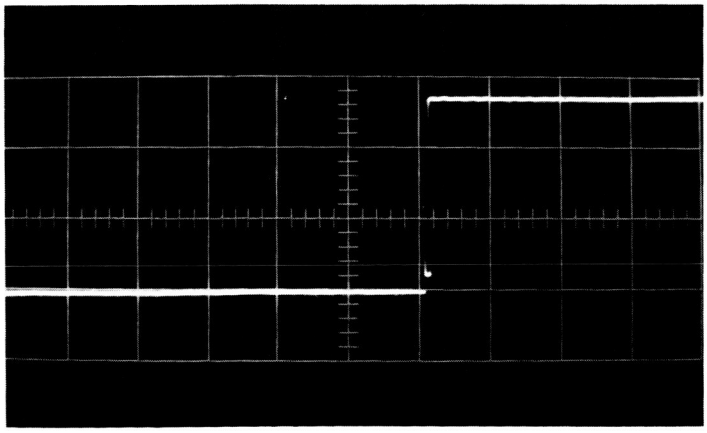
The internal resistance distribution pattern for all 133 initially accepted cells is shown in Graph No. 5.



Vert. 10 MV/CM
Horz. 5 MS/CM

Cell Voltage during C/20 to C Discharge

FIGURE 10



Vert. 100 MV/CM
Horz. 5 MS/CM
Shunt Voltage during C/20 to C Discharge

FIGURE 11

Table 4

Internal Resistance Measurements

Cell No.	001	002	003	004	005	006	007	008	009	010
Int. Res.	3.5 §	3.5	3.7	3.5	3.7	3.7	4.0	3.7	3.9	3.9
Cell No.	011	F012L	F013G	014	015	016	017	018	019	020
Int. Res.	3.9	3.7	4.2	4.0	3.9	3.7	4.2	3.7	4.2	3.7
Cell No.	021	022	023	024	025	026	027	028	029	030
Int. Res.	3.5	3.5	3.7	3.3	3.7	3.7	3.5	3.7	3.7	4.0
Cell No.	031	032	033	034	035	036	037	038	039	040
Int. Res.	3.5	3.3	3.7	3.9	4.9	4.2	3.5	4.2	3.7	3.7
Cell No.	041	042	043	044	F045	046	047	F048	049	050
Int. Res.	3.9	4.6	4.4	3.9	3.9	4.2	3.7	--	3.7	3.5
Cell No.	051	052	053	054	F055L	056	057	F058L	059	060
Int. Res.	3.9	3.9	4.2	3.9	3.9	3.9	3.5	4.2	4.0	3.7
Cell No.	F061X	062	063	064	065	066	067	068	F069S	070
Int. Res.	--	4.7	4.7	3.9	3.5	4.0	3.9	3.7	3.7	3.9
Cell No.	071	072	073	074	075	F076L	F077X	078	079	080
Int. Res.	3.9	4.0	3.9	4.7	4.9	4.2	---	3.9	4.2	4.2
Cell No.	F081	082	F083	F084	085	086	F087	088	089	090
Int. Res.	4.4	3.7	4.4	3.9	4.4	4.2	---	4.2	4.4	4.2
Cell No.	091	092	093	094	095	096	097	098	099	100
Int. Res.	3.9	4.6	4.9	4.0	4.4	3.9	4.7	4.6	4.4	4.6
Cell No.	F101X	102	103	F104L	105	106	107	108	109	110
Int. Res.	---	4.6	4.9	4.0	3.9	4.6	4.4	3.9	4.2	3.9
Cell No.	111	F112G	F113X	F114X	115	F116X	F117X	F118X	F119X	120
Int. Res.	3.9	3.7	4.0	3.9	3.9	4.0	---	---	---	3.9
Cell No.	F131X	F132X	F133X	F134X	F135X	F136X	F137X	F138X	F139X	F140X
Int. Res.	4.6	4.0	4.9	4.6	---	4.6	3.9	3.7	4.4	3.7
Cell No.	193	194	195	196	197	198	F199T	200		
Int. Res	3.7	3.9	3.7	3.9	4.0	3.9	---	4.0		

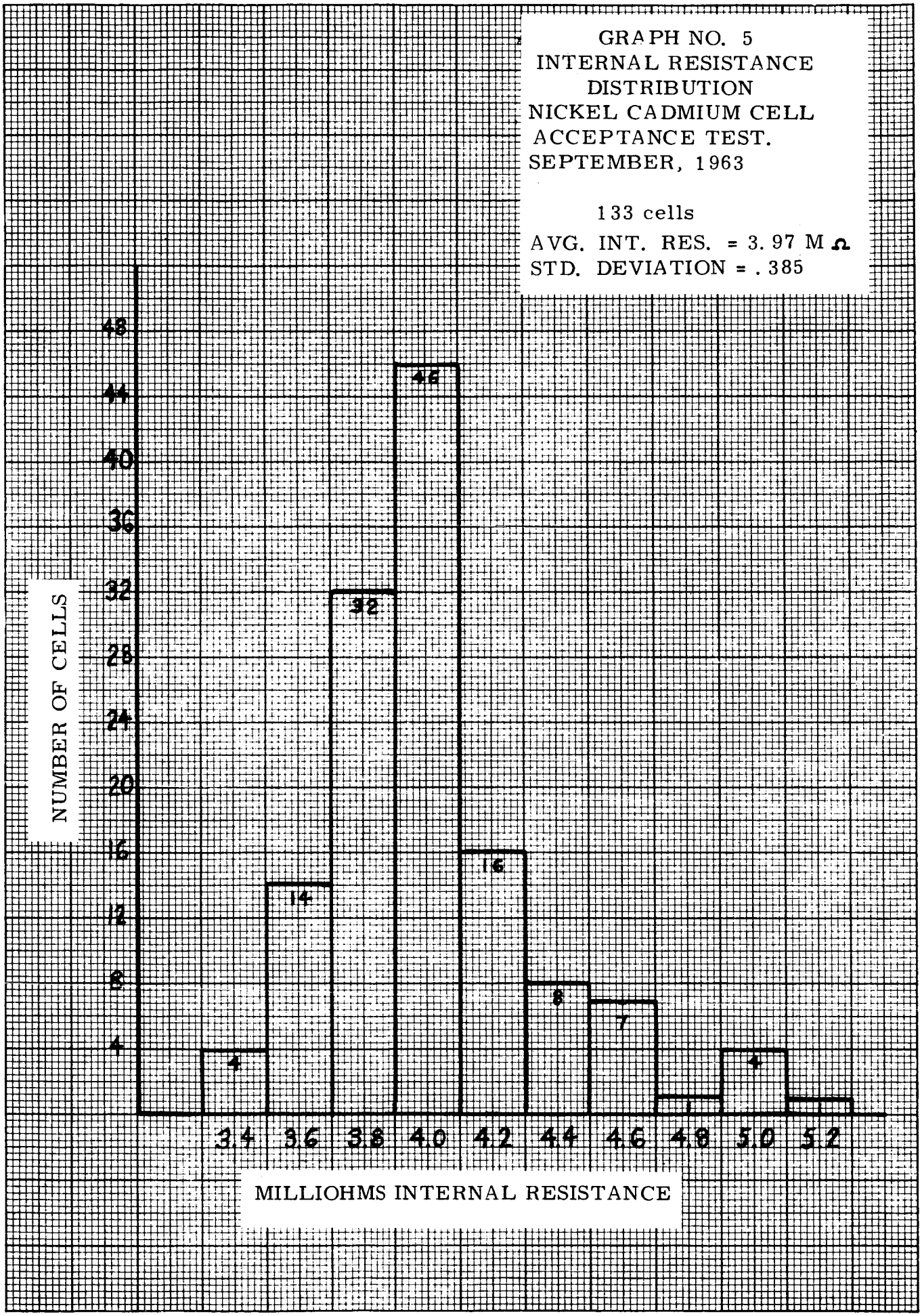
Table 4 (continued)

Cell No.	201	202	203	F204	205	206	207	208	209	210
Int. Res.	3.9	3.7	3.9	---	4.2	4.2	4.6	3.7	4.4	5.1
Cell No.	211	212	213	214	215	216	217	218	219	F220
Int. Res.	4.2	3.9	3.7	3.3	3.5	3.7	3.5	3.7	3.3	----
Cell No.	221	222	223	224	225	226	227	228	229	230
Int. Res.	4.7	3.9	3.7	3.9	4.4	4.2	3.9	3.9	3.9	3.7
Cell No.	F121X through F192X failed acceptance test									
Cell No.	231	F232X	F233X	F234X	F235X	F236X	F237X	F238X	F239X	F240X
Int. Res.	3.5									

§ All internal resistance values in milliohms.

Legend

Prefix	F____ failed cell
Suffix	S____ internal short
	X____ overvoltage
	G____ blocked gauge
	L____ caustic leak
	T____ malformed terminal


GRAPH NO. 5
INTERNAL RESISTANCE
DISTRIBUTION
NICKEL CADMIUM CELL
ACCEPTANCE TEST.
SEPTEMBER, 1963
133 cells
AVG. INT. RES. = 3.97 MΩ
STD. DEVIATION = .385
NUMBER OF CELLS
48
44
40
36
32
28
24
20
16
12
8
4
4
14
32
46
16
8
7
1
4
1
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
5.2
MILLIOHMS INTERNAL RESISTANCE

3.5 Cell Selection

Final selection of all cells to be used in the phase two portion of this project cannot be made until the previously mentioned pressure transducer equipped cells have been received and processed through the acceptance tests.

A preliminary cell selection has been made, however, using the standard deviation of cell capacity and the average cell capacity as a criteria. Using this data the following 15 initially accepted cells were rejected.

MFG'S SERIAL NO.	CONTRACTORS ASSIGNED CELL NUMBER
2869	1
3124	22
3110	39
3128	35
3162	50
3156	51
3121	82
3111	98
2925	194
2891	201
2927	202
2924	207
2900	219
2901	222
2892	223

After rejection of the above cells, the average ampere-hour capacity of all remaining cells was 6.329 ampere-hours.

4.0 Summary

The average ampere-hour capacity of all 133 initially accepted cells was 6.340 ampere-hours. After rejection of 15 of these cells on the basis of capacity deviation, the average decreased to 6.329 ampere hours.

The average positive (PSIA) terminal pressure for Capacity Test charge no. 3 was 8.86 PSIA, (88 cells) and the average negative (IN. of Hg.) terminal pressure for this charge was -1.66 IN. of Hg. (6 cells).

The Capacity Test charge no. 3 average terminal voltage was 1.420 volts, and the average internal resistance for all 133 initially accepted cells was 3.98 milliohms.

Of the 239 cells received from the government, 121 were rejected. Table 5 identifies each rejected cell along with the cause of failure. Table 5 is condensed below:

Reason for Rejection	No. of Cells
Caustic Leak	6
Internal Short	4
Blocked Gauge	2
Overvoltage	85
Malformed Terminal	1
Internal Short and Overvoltage	4
Capacity Deviation	15
Caustic Leak and Internal Short	1
Caustic Leak and Overvoltage	3

The results of testing on the expected twelve pressure-transducer equipped cells will be furnished at a later date in a supplemental report.

Table 5

Rejected Cells

Test Cell No.	Reason for Rejection
1	Capacity deviation
12	Leak at + terminal
13	Blocked pressure gauge
22	Capacity deviation
35	Capacity deviation
39	Capacity deviation
45	Leak at + terminal
48	Overvoltage
50	Capacity deviation
51	Capacity deviation
55	Leak at + terminal
58	Leak at - terminal
61	Overvoltage
69	Shorted internally
76	Leak at + terminal and int. short
77	Overvoltage
81	Overvoltage
82	Capacity deviation
83	Overvoltage
84	Leak at + terminal
87	Shorted internally
98	Capacity deviation
101	Overvoltage
104	Leak at + terminal
112	Blocked pressure gauge
113	Overvoltage
114	Overvoltage
116	Overvoltage
117	Overvoltage
118	Overvoltage
119	Overvoltage
121 thru 192	Overvoltage: also no. 130, 135, 170 and 174 shorted internally, and 142 leaking.
194	Capacity deviation
199	Malformed negative terminal
201	Capacity deviation

Table 5 (continued)

Test Cell No.	Reason for Rejection
202	Capacity deviation
204	Shorted internally
207	Capacity deviation
219	Capacity deviation
220	Shorted internally
222	Capacity deviation
223	Capacity deviation
232	Overvoltage
233	Overvoltage
234	Overvoltage
235	Overvoltage
236	Overvoltage
237	Caustic leak and overvoltage
238	Caustic leak and overvoltage
239	Overvoltage

Table 6

Manufacturer's Cell Serial Numbers Verses Test Assigned Numbers

Test Cell No.	Mfg's Serial No.	Test Cell No.	Mfg's Serial No.
00001	2869	00041	3155
00002	2874	00042	3154
00003	2858	00043	2862
00004	2854	00044	3114
00005	2852	00045	2873
00006	2887	00046	3141
00007	2870	00047	3125
00008	2884	00048	2027
00009	2851	00049	3148
00010	2853	00050	3162
00011	3145	00051	3156
00012	2863	00052	3116
00013	2856	00053	2861
00014	2882	00054	3112
00015	3129	00055	2876
00016	3142	00056	3144
00017	3151	00057	3113
00018	3149	00058	2850
00019	2872	00059	3108
00020	3130	00060	3160
00021	2871	00061	2025
00022	3124	00062	2881
00023	2865	00063	3158
00024	3120	00064	2831
00025	2886	00065	2848
00026	3131	00066	2866
00027	2878	00067	3123
00028	2888	00068	2826
00029	3109	00069	3127
00030	3139	00070	2825
00031	2879	00071	2838
00032	3159	00072	3164
00033	2860	00073	2836
00034	3118	00074	2877
00035	3128	00075	2829
00036	3126	00076	2839
00037	3117	00077	2142
00038	3153	00078	3165
00039	3110	00079	2841
00040	2867	00080	3143

Table 6 (continued)

Test Cell No.	Mfg's Serial No.
00081	3147
00082	3121
00083	2843
00084	3146
00085	3166
00086	2846
00087	2844
00088	2842
00089	2828
00090	2855
00091	3161
00092	2845
00093	2837
00094	2827
00095	2830
00096	3132
00097	2880
00098	3111
00099	3150
00100	3115
00101	2248B
00102	2868
00103	2840
00104	2833
00105	2835
00106	3119
00107	3458
00108	2849
00109	2832
00110	2883
00111	2847
00112	3457
00113	2090
00114	2323
00116	2325
00115	3122
00117	2328C
00118	2242B
00119	2367
00120	2834

Test Cell No.	Mfg's Serial No.
00121	2250B
00122	2062
00123	2102
00124	2244B
00125	2246B
00126	2178A
00127	2196B
00128	2057
00129	2360
00130	2094
00131	2040
00132	2063
00133	2368
00134	2134
00135	2110
00136	2067
00137	2331C
00138	2048
00139	2096
00140	2059
00141	2358
00142	2183B
00143	2371
00144	2181A
00145	2200B
00146	2195B
00147	2361
00148	2058
00149	2357
00150	2137
00151	2115
00152	2192B
00153	2326
00154	2213A
00155	2022
00156	2352
00157	2258B
00158	2363
00159	2053
00160	2033

Table 6 (continued)

Test Cell No.	Mfg's Serial No.
00161	2082
00162	2297C
00163	2088
00164	2124
00165	2028
00166	2023
00167	2146
00168	2038
00169	2133
00170	2130
00171	2129
00172	2036
00173	2238B
00174	2132
00175	2140
00176	2121
00177	2131
00178	2127
00179	2226A
00180	2139
00181	2117
00182	2114
00183	2104
00184	2029
00185	2141
00186	2135
00187	2241B
00188	2251B
00189	2144
00190	2026
00191	2118
00192	2125
00193	2894
00194	2925
00195	2898
00196	2931
00197	2926
00198	2929
00199	2915
00200	2896

Test Cell No.	Mfg's Serial No.
00201	2891
00202	2927
00203	2902
00204	2904
00205	2911
00206	2895
00207	2924
00208	2907
00209	2934
00210	2928
00211	2922
00212	2930
00213	2932
00214	2914
00215	2935
00216	2910
00217	2890
00218	2906
00219	2900
00220	2923
00221	2912
00222	2901
00223	2892
00224	2905
00225	2899
00226	2920
00227	2916
00228	2908
00229	2909
00230	2893
00231	2919
00232	2355
00233	2412
00234	2534
00235	2407
00236	1273
00237	2406
00238	2527
00239	2-29